

Around Gaia Alerts in 20 questions

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Abstract.

Gaia is a European Space Agency (ESA) astrometry space mission, and a successor to the ESA Hipparcos mission. Gaia's main goal is to collect high-precision astrometric data (i.e. positions, parallaxes, and proper motions) for the brightest 1 billion objects in the sky. These data, complemented with multi-band, multi-epoch photometric and spectroscopic data collected from the same observing platform, will allow astronomers to reconstruct the formation history, structure, and evolution of the Galaxy.

Gaia will observe the whole sky for 5 years, providing a unique opportunity for the discovery of large numbers of transient and anomalous events, e.g. supernovae, novae and microlensing events, GRB afterglows, fallback supernovae, and other theoretical or unexpected phenomena. The Photometric Science Alerts team has been tasked with the early detection, classification and prompt release of anomalous sources in the Gaia data stream. In this paper, we discuss the challenges we face in preparing to use Gaia to search for transient phenomena at optical wavelengths.

Keywords. space missions: Gaia, supernovae: general, gravitational lensing, novae

1. Where, how and when?

Gaia will be launched from ESA/Kourou (French Guyana) onboard a Soyuz-Fregat rocket in June 2013. Deployment will be at the L2 Lagrange Point, with the first community release of alerts expected in mid 2014 (internal verification will begin in early 2014). The mission is scheduled to end in 2018–2019.

2. What telescopes will Gaia have?

Gaia will be equipped with two 1.45x0.5m primary mirrors, forming two fields of view separated by 106.5 degrees. The light from both mirrors will be imaged onto a single focal plane. Gaia will reach down to V=20 in the Astrometric Field detectors.

3. What instruments will Gaia have?

Each object traverses through the focal plane (4.4 sec per CCD), see Figure 1.

SM: Objects are detected in Sky Mapper CCDs, and are allocated windows for the remaining detectors.

AF: Source positions and G-band magnitudes are measured in the Astrometric Field CCDs (platescale $\sim 0.04 \times 0.1$ milliarcsecs).

BP/RP: Low-dispersion spectro-photometry (330-680nm, 640-1000nm) in 120 samples.

RVS: Intermediate-dispersion ($R \sim 11,500$) spectroscopy (847-874nm) around the Calcium Infrared triplet to V<17 mag.

‡ name pronunciation: *Woo-cash Vi-zhi-kov-ski*

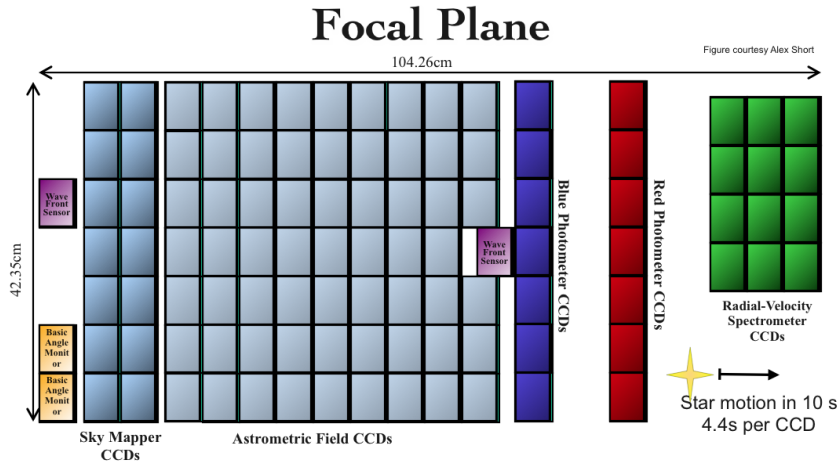


Figure 1. Focal plane of Gaia.

4. What is the data latency?

Gaia will be visible from the Earth for only 8h a day. All data from the last 24h will be downlinked during a contact. After initial processing, alerts will be issued from between a couple of hours, and up to 48 hours, after the observation.

5. What is downloaded?

Most of the sky is empty. Gaia will only transmit small windows around stars detected at each transit on the Star Mapper CCDs and associated data.

6. How does the scanning law allow for full sky coverage?

Gaia has a pre-defined plan for scanning the sky. The spin axis is maintained at a 45 deg angle from the Sun, with a period of 6h. For details see Figure 2.

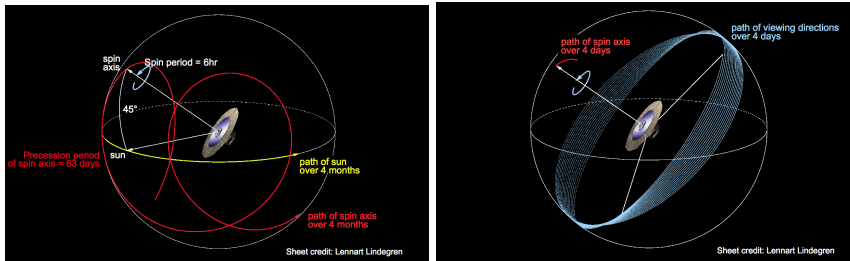


Figure 2. Nominal Scanning Law principles for Gaia satellite.

7. What is the typical sampling?

On average, each object will be observed 80 times, though at the Ecliptic nodes, objects are scanned in excess of 200 times. Observations occur in pairs (two FOVs), separated by ~ 2 hours. The next pair will typically occur between 6 hours and ~ 30 days later.

8. What is the precision of the instantaneous photometry and astrometry?

In a single observation (transit) the photometry will reach milli-magnitude precision at $G=14$, and 1% at $G=19$. The astrometric precision will be in the range $20\text{--}80\mu\text{as}$ at $G=8\text{--}19$.

15 (see Figure 3 for the effects of gating), falling to $600\mu\text{as}$ at $G=19$. This astrometric precision will only be reached later in the mission.

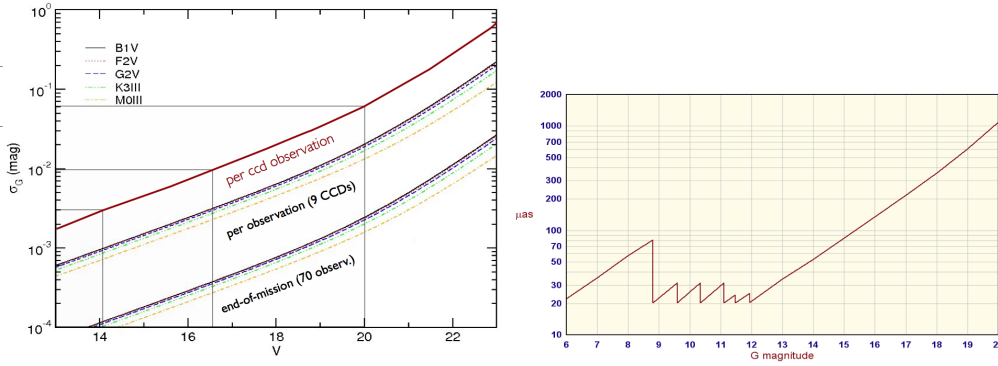


Figure 3. Precision of instantaneous photometry and astrometry of Gaia satellite. (from Varadi et al. 2009).

9. How will the anomalies be detected?

Using simple recipes:

1. Compare the most recent observation with the historic data available.
2. Inspect for unexpected changes.
3. No history? - new transient!

10. How will the anomalies be classified?

1. From the light-curve.
2. Using low-dispersion BP/RP spectroscopy.
3. Cross-matching with archival data.

11. How will the BP/RP spectra be used?

Self-Organizing Maps (Wyrzykowski and Belokurov (2008)) built from the low-dispersion spectra can confirm a non-stellar nature, classify Supernova types, measure Supernova ages and possibly even constrain the redshift.

12. How will the alerts be disseminated?

Skyalert.org, email, www server, Twitter, iPhone app, etc.

13. What will be in an alert?

The coordinates, a small cutout image from the SM, the Gaia light-curve, a low-resolution spectrum at the trigger, the classification results, and the cross-matching results.

14. What will the the main triggers be?

Supernovae, Classical novae, dwarf novae, Microlensing events, Be stars, GRB afterglows, M-dwarf flares, R CrB-type stars, FU Ori-type stars, Asteroids, Surprises.

15. How many Supernovae will Gaia detect over 5 years?

6000 SNe expected down to $G=19$. About 2000 will be detected before the maximum (Belokurov and Evans (2002)).

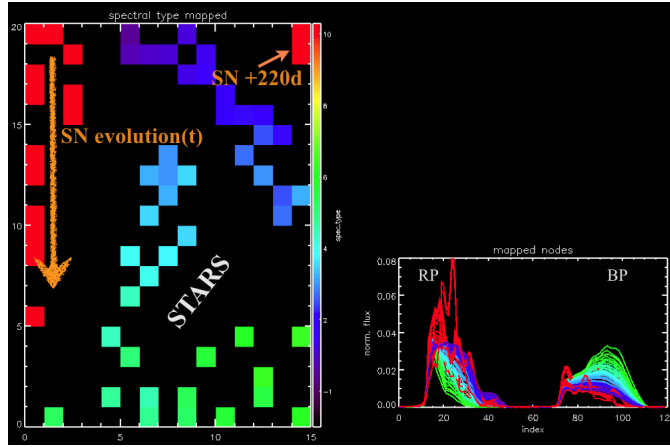


Figure 4. A Self-Organizing Map (left) can distinguish between different spectral types of stars and supernova at different epochs, as built from Gaia synthesized BP/RP spectra (right).

16. How many Microlensing Events will Gaia detect?

1000+ events (mostly long $t_E > 30d$) are expected to be detected photometrically, mainly in the Galactic bulge and plane. Astrometric centroid motion will be detectable in real-time (for larger deviations of about $100\mu as$) in on-going events, and alerts may be triggered to obtain complementary photometry (Belokurov and Evans (2003)).

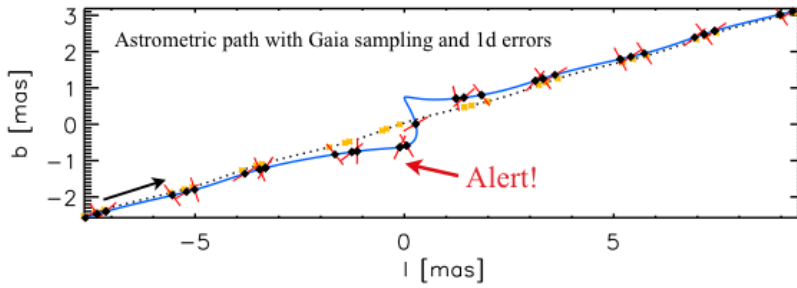


Figure 5. Trajectory of a source due to proper motion and centroid shift during a microlensing event.

17. Will Gaia alert on GRB optical counterparts?

Gaia sampling and data latency is not good for alerting on GRBs. However, we still expect to detect 1-2 bright on-axis afterglows and 5-15 orphan afterglows (Japelj and Gomboc (2011)).

18. How many Asteroids will Gaia see?

About 250,000 asteroids (mostly known). Alerts on new asteroids and NEO candidates will be based on unsuccessful star matching.

19. What about known anomalous objects?

Such objects can be added to the **Watch List**. Every time Gaia observes them, their data will become available for inspection.

20. How can I get involved now?

- **with my telescope time:** prepare for Gaia Alerts, register at Skyalert.org, set-up your alerts on CRTS stream (Drake et al. (2009)) (SNe, CVs, blazars, etc.), follow-up the alerts, contact us with your data!

- **with my scientific interests:** suggest what would be worth detecting and alerting on, propose detection algorithms and classification techniques, suggest interesting known targets to be observed.

More information on the web:

- Gaia ESA web pages: <http://gaia.esa.int>
and <http://www.rssd.esa.int/index.php?project=GAIA&page=index>
- Gaia Science Alerts Working Group wiki: <http://www.ast.cam.ac.uk/ioa/research/gsaawg/>
- original poster on Gaia Alerts presented at the IAU Symposium in Oxford in September 2011: http://www.ast.cam.ac.uk/ioa/wikis/gsaawgwiki/index.php/Detection_system

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